

The Problem about Technology in STEM Education: Some Findings from Action Research on the Professional Development & Integrated STEM Lessons in Informal Fields

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Author note: This research was supported by a grant from MEXT/JSPS KAKENHI Grant Number: 23300283, and a special grant for the Local Supporting Project from the Shizuoka University. The field provided by Fujieda-city, and two professors, Dr.Kumano and Prof. Gunji, as a course for Undergraduate Juniors to foster the skills for development of learning materials. Also, this study had supported by Undergraduates who worked as teachers in the lesson, Kazutaka Ohashi, Shohei Okawa, Sohichiro Nishitani, Takayuki Shirasuna, Yuto Muto.

ABSTRACT

Since 2013, the authors' Japanese team in the Department of Science Education at Shizuoka University has held trials of STEM Education in informal fields as participatory action research (e.g., Science museum in Shizuoka, Lifelong Learning Center in Fujieda City, and STEM Summer camp) for the preparation for implementing STEM education in public schools and for proposing science education reform in a Japanese context. Problems in preparing STEM lessons include numerous new instructional materials and programs and emerging specialized schools. In addition, while most of these initiatives address one or more of the STEM subjects separately, there are increasing calls for emphasizing connections between and among the subjects (Honey, Pearson and Schweingruber, 2014). Unfamiliar problems for Japanese teachers are, What is Engineering? What is Design? and How can they be implemented in lessons? While gathering STEM learning materials to implement in their STEM Summer Camp, the authors noticed a pattern with which to develop a STEM lesson and developed a template "T-SM-E" in reference to prior STEM studies. After the STEM Summer Camp, the authors introduced the model in the pre-service teacher preparation program. As a result, the authors received suggestions about how teachers can develop integrated STEM lessons, how undergraduate (UG) teachers can implement it in their lessons, and how teachers can assess student learning in their STEM lessons. From standard based student assessments and reflections written by the UG teachers, the authors found that it was difficult for the UG teachers to include technology in their lessons, and their assessment also indicated that the students did not show performance proficiency in technology. The authors discuss this existing problem in the Japanese education system.

Keywords:

STEM integration, T-SM-E, participatory action research, professional development, STEM learning materials

Many countries are rapidly recognizing STEM education as an education reform. What are the aims of the reform, and what problems exist for Japan?

In the United States, the President's Council of Advisors on Science and Technology (PCAST) wrote reports including *Prepare and Inspire: K-12 Education in Science, Technology, Engineering and Mathematics (STEM) for America's Future* (2010) and *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics* (2012). These reports indicated that one facet of STEM Education is not only a slogan for science education reform to increase the proportion of the population who can engage in the STEM workforce, but it also aims to foster citizens who have enough resourcefulness to solve the "issues" in our world. Bybee (2013) pointed out the differences of this STEM Education reform from other reforms: ① *Addressing global challenges that citizens must understand*; ② *Changing perceptions of environmental and associated problems*; ③ *Recognizing 21st-century workforce skills*; and ④ *Continuing issues of national security*.

In addition, national calls for improvement of STEM education are effecting changes in policy, particularly in academic standards. Thus, states have decided to include engineering in the academic standards and thereby point out the necessity of corroboration of teachers in different subjects (Roehrig, Moore, Wang and Park, 2012). *The Next Generation Science Standards* (NGSS) were released in April, 2013 and made a commitment to integrate "engineering design" into the structure of science education by raising it to the same level as scientific inquiry. In reviewing state standards, engineering skills and knowledge were found in those of 41 states. Most items rated as engineering through strict coding were found in either science or technology and vocational standards (Carr, Bennett, & Strobel, 2012). In the U.S., Postal (2013) pointed out that the Common Core standards (2009) in the areas of math and English language arts have been adopted by 45 states, and teachers are using these standards to develop courses, select textbooks and implement their lessons. Efforts by teachers to try to accommodate these standards are immeasurable. Roehring *et al.* (2012) point out the needs of integrated STEM curricula (in school settings) and professional development, which can support the teachers who confront the challenges of implementation of integrated STEM class by changing their practices.

What about Asian countries? In Japan, educators have continued to apply the "Course of Study" as the National Curriculum (MEXT, 2008-2009, 2010) to which they are legally bound. In this educational system, Engineering was never taught in K-12 classrooms, except in specialized upper secondary schools. If STEM is to be included in our science classes or the curriculum as an integrated learning class, how can we apply the unfamiliar activities? There are many questions and problems to solve, and a need to know where to apply it in our public education system.

Japan needs evidence that integrated STEM learning will become a fruitful way to improve students' knowledge, skills, or abilities to survive in this complicated world and its future. For this purpose, the authors thought that they needed to make it easily implementable by teachers in schools. Their research questions asked: How can teachers make integrated STEM learning in their classes, make various learning materials for it, and get theoretical background knowledge, which is supported by sufficient educational practices?

In this study, the authors developed STEM lesson trials using a Participatory Action Research method. In the study, they developed a template (T-SM-E) to make it easier to develop STEM learning materials. The template can be used in pre-service teachers' training, in the assessment of STEM learning, in attempting to define integrated STEM content, and in identifying problems related to professional development in Japan. This research was established for future study and implementation of integrated STEM education.

Informal STEM Education & Development of Japanese STEM Trials

In 2013, the authors started the “Shizuoka STEM Junior Project”, implemented in two cities, Shizoka and Fujieda, and later expanded to four cities in 2014 (Figure 1).

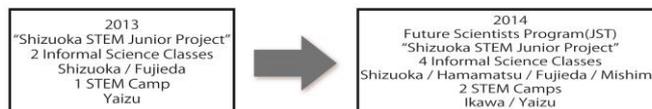


Figure 1. Shizuoka STEM Junior Project

In 2014, the project continued as the “Future Scientist Program”, which was supported by a grant from the Japan Science and Technology Agency (JST).

This article focuses on and explains the program in 2013 and provides some perspectives from the Participatory Action Research (PAR) to improve its activities and future implementation in public schools. In PAR, some practitioners in the organizations studied teamed up with professional researchers in designing projects, gathering and analyzing data, and utilizing the findings in action projects (Whyte, 1989). PAR is characterized by the active participation of researchers and participants to collect data and reflect on the action itself in the co-construction of knowledge (Baum, MacDougall, and Smith, 2006; McIntyre, 1997, 2008). Table 1 shows the class schedules of the project in 2013.

Table 1. Schedules of the Project in 2013

Date	Contents	Main Educators
7/13	Best air plane Roller Coaster	Dr. Kumano and Ph.D. Candidates
7/27	Boomerang, Refrigerant Linear motor car Cartesian diver Gas rocket, Make alloy Domino Soap bubble inside the water	Undergraduate (UG) Junior students
7/29	STEM Summer Camp	All lab members
8/24	Pumpkin launcher Paper craft UFO	UG Junior students
10/5	Glass harp	Ph.D. Candidates
10/19	Pasta Bridge	UG Senior students
11/9		
11/17	Dagik Earth	UG Senior & Ph.D. Candidates
12/7	Water purification system	UG Junior students
2/1	Small science festival	UG Junior students

In this schedule, the authors studied the development of STEM learning materials and UG students’ professional development in STEM Education. The details can be separated into two Phases, “Before STEM Summer Camp” and “After STEM Summer Camp”. In the following sections, the authors discuss the results from these phases with methodologies that were adopted for the activities and data results.

Development of the STEM Learning Materials

During the first year of the Japanese STEM trial, the authors started their STEM summer camp plan by investigating STEM learning materials from previous models. They had noted that early cues or hints from the teacher or illustrations in instructional materials could lead students to favor some solutions over others (Crismond & Adams, 2012).

There were many websites that provided learning materials for STEM. However, for the Japanese teams, as the authors stated in the introduction, engineering (E) was important as a starting point for their STEM trial. Therefore, they chose a website named “eGFI” by the American Society for Engineering Education (ASEE) and the book *STEM Lesson Essentials* (Vasquez, Comer, & Sneider, 2013). In addition, the authors studied a STEM trial by Korean teams, and made some self-developed materials. As a result, the learning materials adopted for the camp programs were *Pumpkin-launcher*, *Solar-cooking*, *Water-floater*, and *Paper-bridge* (eGFI, 2013), *Valued-chair* (Lee, Seo, K. Park, Kim, Y. Park, & B. Park, 2013), *Roller-coaster* (Vasquez et al., 2013 pp.23-24), *Dippers*, *Ottolith*, and *Sui-kin-kutsu* (Authors).

To implement these nine practices in the camp, the authors developed a set of explanation sheets shown in Figure 2. These sheets include five sections: ① Related STEM Contents & Subject Matter; ② Descriptions of “Science” in National Level Curriculums (Course of Study in Japan & NGSS in the US); ③ Summary of Activities; ④ Application to the *Iterative Cycle* on NGSS Appendix I “Define-Develop-Organize (DDO) model” (2013); ⑤ Expected Student Performance based on the *DDO* model. These Explanation Sheets were provided for UG students who worked in the camp as staff (The details of these materials are explained in Saito, Okumura, and Kumano, 2014).

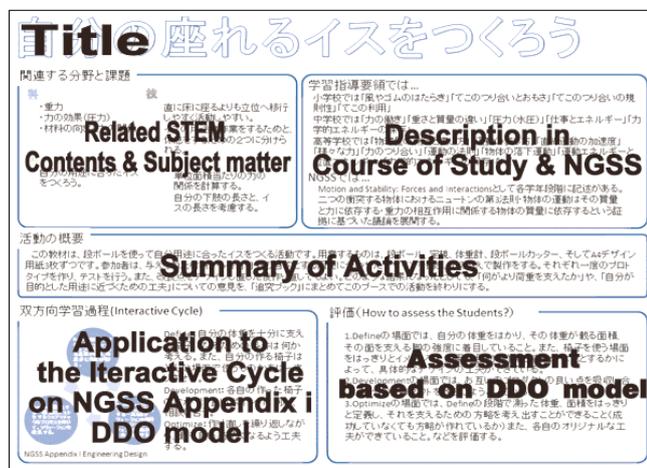


Figure 2. An Example of Explanation Sheet for STEM Learning & Its Materials

The Findings in the “Before STEM Summer Camp” Phase

Several findings shown below emerged after the study about the prior STEM learning materials and some questions about the Engineering centered STEM integration and problems implementing it in Summer Camp.

- There is a sequence pattern (T-SM-E), which we can use to develop a STEM Lesson based on these materials.
- The “Science” learned by the students through integrated STEM activities are not necessarily related to the contents of National Curriculums like Course of study, or the *NGSS*.

- The DDO model is prepared as an assessment of design activities; however, it cannot be used to assess the learning of Science, Mathematics, or Technology.
- Even if the related information were indicated on Explanation Sheets, UG students could not easily understand the STEM contents as Science (because their major was Science Education, not Technology, Engineering, or Mathematics Education).

The questions that resulted from these findings were the following:

- How can teachers define the STEM contents, which will be integrated in the learning?
- Are the contents, which are to be learned from the Engineering contexts the same as scientific concepts in traditional science education?
- How can teachers assess STEM learning?

To find possible STEM learning materials that can be applied to our Course of Study, we need many examples of such practices. However, the published examples do not focus on the integration of contents (Roebuck & Warden, 1998). It still exists as a problem for the preparation for integrated learning in 2014.

In the camp preparation, the authors and some camp staff members realized that the learning materials had been labeled as Technology (products as a result of Engineering). Therefore, they tried to generate Scientific (S) or Mathematical (M) activities during the lesson study for the development of prototypes. These sequences similarly indicated T-SM-E; even though developers had already corrected the Engineering problems. The authors speculated that the sequence could help teachers identify the STEM contents that will be integrated in the learning, and developed the T-SM-E method by including some ideas from prior studies (Table 2). Using this method, the authors implemented the next activities as professional development for the undergraduate students who also worked as practitioners in the project.

To develop this method, the authors aimed to align the learning sequences, which were explained in *STEM Lesson Essentials* (Vasquez *et al.* 2013, pp.38). The authors of this book refer to *A Framework for K-12 Science Education* (NRC, 2012), *Common Core* (2010) and developed a table of the learning sequences. In addition, Bybee (2011) pointed out that in middle school level, "science teachers can begin with the technologies already used". Furthermore, Roehring *et al.* (2012) concluded that *the majority of science teachers focus on product and the majority of mathematics teachers focus on process during their engineering design lessons*. This method also aimed to support these characteristics of teachers and should be revised by teachers over time.

Table 2. T-SM-E Method Provided for Undergraduate Students

	Summary	Teacher Points	Resources
T	In this phase, teachers find Technology that exists in our world interesting. Technology is a result of Engineering. Therefore, some products will be defined by teachers. After that, teachers study about the history or role of the technology, and identify the needs of why the products were developed throughout history. Teachers develop a possible solution, which is likely to be addressed by the students in class.	<ul style="list-style-type: none"> • Find interesting stories about the technology for the class introduction. • Predict how students will work in the activity. • Define limitation of the materials. • Define what kinds of factors affect the quality of the possible solutions. • Identify dangers during the development. • Don't think that the students will develop the same process as teachers; prepare for diverse student learning. 	<ul style="list-style-type: none"> • Books or Internet websites about the Technology; • Companies that provide the product; • Identify pre-practices by others. (Sometimes it has already been done by someone).
SM	This phase partially overlapped with phase "T". Teachers think about the related Science Contents, which support the development of the students' solutions. It should be considered with the standards assigned to the grade levels. Teachers also identify the mathematical factors, which will be investigated by the students to modify their solutions.	<ul style="list-style-type: none"> • The scientific knowledge that students discover in the activities is not necessarily the knowledge that is found in the standards. • If the contents are too difficult for the grade levels, what kinds of regularities or relationships can students find? • For the experiment, what kinds of tools or scales will support their mathematical work? 	<ul style="list-style-type: none"> • National Standards. (Course of Study) • Prefectural Standards. • Textbooks. • Teachers Guide. • Internet Website. • Specialized Books. • School curriculums.
E	To wrap up the TSM contents, teachers try to identify the Engineering Problem which will lead students to the learning naturally. In this phase, teachers try to select the vocabulary words or terms that are used in the engineering problem.	<ul style="list-style-type: none"> • To lead students to the state that they can define their engineering problem by themselves, how can they be challenged to think about the problem? • If necessary, teachers go back to the "T" phase to think again about the needs and limitation of the technology. • One word in the problem statement can affect students' thinking and teachers' preparation. 	<ul style="list-style-type: none"> • Commercial product copies • Needs which were found in phase "T".

Professional Development (PD)

The Activities

In the "After STEM Summer Camp" phase, the authors provided a STEM class in the Shizuoka STEM Junior Project for Undergraduate (UG) junior students as a field course of STEM PD. In this class, UG students became UG "teachers" and learned about the development of learning materials for 30* elementary students. The PD was held as a course in the Department of Science Education in Shizuoka University. Five UG junior year students (year 3) participated in this all year course and prepared their lesson plans from July through February. For the focused lesson, which was held on December 7th (See Table 1), the authors and UG teachers used T-SM-E methods to prepare the STEM learning materials (Water Purification System) beginning November 7th and used standard-based assessment to assess the students' learning December 12th-19th (Table 3).

Table 3. Course Schedules

11/7 ~12/5	Preparation with T- SM-E
12/7	Fujieda-class
12/12 ~12/19	Assessment and reflections

In the lesson, five UG teachers separately took charge of four students* and the students learned with a worksheet that included five tasks such as ① Engineering problems; ② Findings from development; ③ Reason why the solution did not work; ④ Plan for what will be included; and ⑤ Decide how to modify it for the next time. After the lesson (Dec. 12th), UG teachers recorded their students' assessment from the performances and completion of the worksheets in the lesson, and reflected on their own assessments for the next time (Dec.19th). On the assessment sheet, they also recorded their lesson sequences as the appearance of the S-T-E-M in the lessons.

*The senior & graduate students who did not participate in the PD program, and their students, were not included in the data of this study.

In Japan, public schools have adopted Standard-based Assessment and established standards based on the "Model of Standards-based Assessment", which is applied to all contents of Course of Study and provided by the Board of Education in each of the prefectures (e.g., Shizuoka Board of Education, 2002) or by the textbook companies that align curricula to their publications. In addition, the National Institute of Educational Policy Research (NIER) provided *Reference materials for developing Assessment Standards* (2010-2011). There also exist several English articles about similar systems of standards-based grading written by Marzano (2009), and Sciffriny (2008). Teachers in schools are doing assessment based on these materials. This means that UG teachers will work on these methodologies when they become teachers in schools, a main reason why the authors provided these assessments as part of the PD training.

The Water Purification System used as an activity in this study was developed using bottles and several components shown in Figure 3. It was designed by the students for the purpose of solving engineering problems, which were identified by students with UG teachers' guidance during the lesson. One of the engineering problems stated by students on the worksheet is shown in Figure 4.

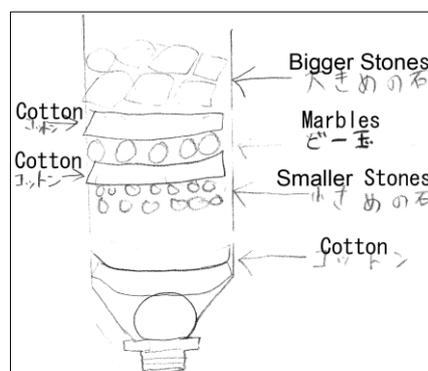


Figure 3. A Design by Students



Figure 4. The Engineering Problem Written by Students

Lesson Assessment Standards

The assessments were done by UG teachers using the two sets of Assessment Standards shown in Table 4. These assessment standards included three comprehensive viewpoints, which related to the contents of S/T/E/M for students (I). (As the rubric criterion it should be specified for each lesson).

Table 4. Assessment Standards for Students

(I) Viewpoints of students	
1	Recognize the role of Technology and its problems in society.
2	Understand the Engineering problem and its constraints.
3	Use Science and Mathematics to solve the problem.

On Standards (I), students were given assessments A, B, or C for each of three viewpoints. If students did any performances or writings that met the standards, they scored a B. Students completing more (above the standards) scored an A. If they did not complete any performance or writings, they scored a C. Although Japanese teachers have to define their levels as numeric evaluation to report it for their parents in school settings, this assessment did not aim to grade students in each level. Teachers are using the assessment to make their next lesson strategies based on these assessments from the students' understanding. The assessments are the records of how students performed or wrote about the expected performance or contents on the standards. Thus, Japanese are calling this a Standards-based Assessment.

In this course, the assessments were recorded on an Assessment Sheet (Figure 5) by UG teachers and discussed with the authors about whether or not the assessment on each viewpoint had enough information about students and matched students' developmental stages. The sequence in their lesson was also recorded on this sheet. Sometimes UG teachers assessed students' learning more strictly. Thus, the authors needed to explain that "in practical settings, things that students could not do are not important; however, the things that students could do are important for their learning". From these comments, some UG teachers changed their assessment. For example, one UG teacher wrote in Figure 5 a reflection that he thought the Filtration was the "S" (Science) part of this learning material. Through his lesson, though he could not support students learning of filtration by chemical absorption, as students can only understand physical filtration. Thus, he changed his assessment to A. He considered chemical absorption too difficult for his students.

Figure 5. Assessment Sheet by UG Teachers and its translation

View points	Lesson Sequences	Student1	Student2	Student3	Student4
1	1	<p>テストの裏の工程を見、何層かにすると浄水できるということを知り、それを参考に作りました。</p> <p>問題点の認識 B Knew the effects of layers from an article. Thus, the student tried it in my lesson.</p>	<p>浄水場で見た経験を生かして、粒の大きさと並べ方に注目して作りました。その理由については自分で考えました。</p> <p>問題点の認識 B Had visited a water purification plant. Thus, the student focused on the size and arrangement and could think about the effects without help.</p>	<p>テストの裏の工程を見、炭が入っている層に必ず必要があるという知識があった。</p> <p>問題点の認識 B Knew that the system needs charcoal or layers from reading an article, too.</p>	<p>浄水場を見に行き、ここで「何層か」層にすることを気が付いた。また話を聞かされたというスタイルで「取り組んでみた」。</p> <p>問題点の認識 C Had visited a water purification plant. Student packed as much material as possible in the bottle.</p>
2	3	<p>層の数を決めるのは、この詰め方どう感じたか、水の様子などは注視してしか観察できませんでした。</p> <p>Although student aimed to spread the components in the bottle, the observations focused on the water current. B</p>	<p>粒の大きさに注いでどちらか上の方が良いか疑問に思った。そこで変えながら実験しました。</p> <p>By focusing on the size, student had a question about which grains should be placed above. Student then changed the factors in the experiment. A</p>	<p>列の中で最初に、層の数を減らしてもきれいに保つことに気が付き、列の数を減らしてあげました。</p> <p>Was aware that the system can have fewer numbers of layers. B</p>	<p>その層のきれいに保つための層が問題か調べるため、層の間に脱脂綿をはさんでみる方法を試しました。</p> <p>Tried to find out the layer which had the problem. Thus, student placed a cotton layer between all of the other layers. B</p>
3	2	<p>同じ水量で水が澄も通るときれいになるときに気が付いた。また、茶の葉が落ちてくることにきれいに保っている感覚を持っている。</p> <p>Was aware that the water became clear with the same patterns of filtration. B</p>	<p>脱脂綿と石の大きさ、物理的要因について考えました。</p> <p>Cotton, sand, the size of the stones etc. Student thought about the physical factors. B</p>	<p>脱脂綿→物理的要因は理解できていた。</p> <p>Was aware that the cotton layer works as a physical filter. B</p>	<p>茶の出てくる量、スピードがきれいに気が付いた。</p> <p>Aware that the speed of the water flows and its amount impacted the clarity of the water. A</p>

In his case, it is possible to say that his next preparation will focus more on how to lead students' understanding about physical filtration or the problems of the technology.

The authors also asked the UG teachers to give reflections on three viewpoints: about the engineering problem, STEM contents, and lesson development on the T-SM-E method as a teacher (II) (Table 5). The reflections by UG teachers are indicated in the next section.

Table 5. Assessment Standards for Students

(II) Viewpoints of UG teachers	
1	Define the Engineering problem to be solved by students in the lesson.
2	Define the contents of T-SM-E parts in the material.
3	Explain how the T-SM-E sequences helped teachers make their material.

Results

Assessment of Student Learning

In Figure 6, the authors show the total scores on Assessment Standard (I) before UG teachers changed their assessment (after conferring with advisors), because in PAR research it is better to describe and analyze the behavior of those studied, as it would occur without the observer's presence (Whyte, 1989).

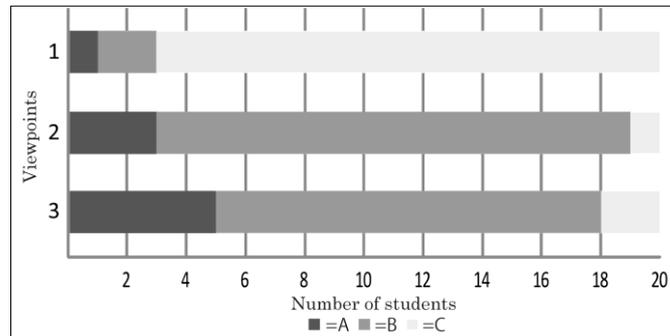


Figure 6. Student Achievement Using Standards-based Assessment

On "Viewpoint 1", one student was assessed as A, and most others were assessed as C. These scores mean that many UG teachers thought their students could not think about the role of technology and its problem during the lesson. For "Viewpoint 2", one student was assessed as C and the others were assessed as B or A. It means that UG teachers thought almost all of their students could understand the engineering problem and its constraints during the lesson. For "Viewpoint 3", 2 students were assessed as C and the others were assessed as B or A, which means that UG teachers felt that most of their students could use science and mathematics to solve the problem.

Statistically, as Table 6 shows, the result of the chi-square test on Excel 2010 indicates that the students' assessments on viewpoints 1, 2, and 3 have a significant difference from the expected values ($p \leq 0.01$). In this calculation, the authors analyzed the data according to Cochran's rule (1954) and combined neighboring grades A and B as an achieved grade because some of the expected values were lower than 5. In addition, according to the Adjusted Residuals, Viewpoint 1 is negative as an achieved grade and positive as an unachieved grade. Also, viewpoints 2 & 3 are positive on an achieved grade (± 2.58). However, the unachieved grade on viewpoints 2 & 3 are not significant as negative (± 1.96).

Table 6 Result of Chi-square Test, Adjusted Residuals & its Power Analysis

Contingency table	Expected value		Adjusted residuals			
	A/B	C	A/B	C		
1	3	17	13.33	6.67	-5.94	14.76
2	19	1	13.33	6.67	10.06	-1.24
3	18	2	13.33	6.67	9.06	-0.24

p value= 1.413E-08 Power(1-β err prob)=0.99
 $\chi^2 = 36.15$ Cramer's Value=0.77

Reflections of the UG teachers on Assessment Standards (II)

On Assessment Standard (II), UG teachers wrote reflections like the examples below. These reflections were written on the other side of the Assessment Sheets and some additional sentences were added in () by the authors for clear understanding of the context.

UG Teachers' reflections about the engineering problem (For Viewpoint 1)

- (Instead of thinking about how I can conduct my lesson,) I could use my time to communicate with the students more, because I predicted the engineering problem that students would like to solve. From the discussion with the other UG teachers, I could think about and find (not only Science, but also) many aspects (STEM) of this learning material.
- I prepared a story about an emergency drill for the students and asked about the things that are necessary after a disaster. They answered that "water" is necessary to make meals, to drink, to wash laundry, and to take a bath. So, I asked, "Does such water exist after a disaster?" They answered "No" so they then wanted to make contaminated water useful by themselves. This led them to the engineering processes.
- To prepare the lesson, I couldn't define the problems of Technology.

Reflection about STEM Contents (For Viewpoint 2)

- As a concept I had all STEM in my mind. But, in the lesson, I couldn't connect with all of the ideas.
- I couldn't make it specific about Technology.

Figure 7 is one part of reflections about the contents written by the UG teachers. This UG teacher understood the contents of the "S" part as terms or concepts of Sciences like "Chemical Filtration" or "Physical Filtration" and the "M" part as measurable points in the system.

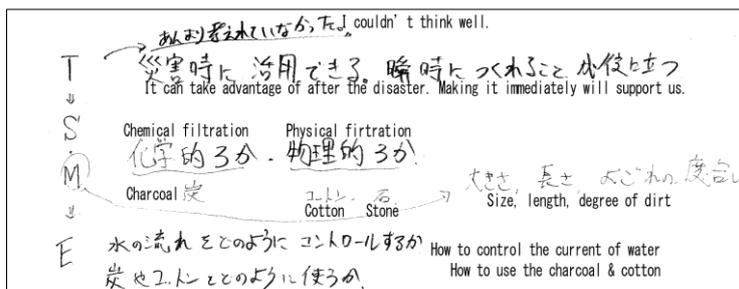


Figure 7. A Reflection of a UG Teacher about the Content

Reflections about the T-SM-E Methods (For Viewpoint 3)

- I used the T-SM-E sequence during my preparation. When we decided on the material for a Water purification System, I looked around for many ways Technology and S&M can connect to E on this model. When I did this lesson, I started from E, and progressed to SM-T. It made me lose focus of T.
- I could do T-S-E, but the M could not be added.
- Basically, I did my lesson on the T-SM-E sequence, too. But I added E after the T to give my students a larger perspective through the activity.
- I used T-E-SM-T.

Discussion

Teachers experienced difficulty including “Technology” in the lessons. The Japanese UG teachers understood that they could not provide enough of a chance for their students to learn about Technology and it might have influenced the learning result. The authors discussed with the UG teachers why they believed they could not provide enough information about technology. The teachers replied that they thought the definition of technology was a little different from their experiences. In Japan, there is a subject in the curriculum called “Technology” in the junior high school level, in which students learn about fixed themes, such as “Technology related to material and processing”, “Technology related to energy transformation”, “Technology related to biological development”, and “Technology about information” with woodworking, electrical working, metalworking, or cultivation, and so on. Therefore, though its objectives as a subject (Table 7) are similar to STEM, UG students thought of “Technology” as involving vocational skills. In other words, there was a gap between the historical recognition and the objectives of the Course of Study. As a professional development subject, there needs to be more study about the nature of technology. On the other hand, an UG teacher who put “A” on Viewpoint 1 (I) prepared a story about technology of the water purification system (See teacher’s reflection about the Engineering Problem). This may show that a good description or illustration about technology leads students to the engineering design processes naturally, an important point to remember when preparing and implementing a STEM lesson.

Table 7. Objectives of “Technology” in the Course of Study

“Through practical and experiential activities like hand crafts, students get the basic and fundamental skills and knowledge about Materials and Processing, Energy Transfer, Biological Development, and Information. In addition, students deepen their understanding about relationships between technology and society or environment, and foster the abilities and attitudes to properly evaluate and take advantage of the technology.”

For the “SM” component, teachers might confuse the application of scientific concepts. UG teachers identified the “S” as “Physical Filtration” and “Chemical Filtration”. However, they could not identify whether the level of understanding is appropriate for the students’ developmental levels. The contents, which appear in the STEM learning for elementary levels may be different from such defined concepts as Science. As the *NGSS* shows, it would seem to be more like applications of Science. UG teachers need to define the concepts as students’ words that would be used in the activity. In addition, teachers need a clear application of “M” using the technology. Of course, it is possible that this includes using mathematics like researchers or industrial engineers do. However, in a practical setting, teachers will need to identify the measurable points by students, like size, length, degree, and so on. These scales should have units and be available as mathematical work.

For the “E” component, students were able to define their Engineering Problem and UG teachers felt that they could support the definition given by students. On this point, it is possible to say that the design activity suggested a goal, which was achievable for many of the students and it is a possible assessment point in the STEM education framework.

Although UG teachers felt they understood the meaning of the T-SM-E Method and they can develop STEM lessons by themselves, they also reflected from the sequence records that they felt the engineering problem should appear sooner in their lessons than previously thought. As some UG teachers mentioned in the reflection, E-SM-T or T-E-SM may be a better sequence for students’ learning. After working on a template, UG teachers accelerated their pedagogical thinking and improved their lessons individually.

Conclusion

The authors think that this T-SM-E method is a reasonable and effective template for teachers to get used to and to assist in development of integrated STEM lessons. Teachers can develop a variety of kinds and sequences of lessons from understanding its contents. To clarify the problems that exist in integrated STEM learning, a variety and number of implementation strategies are needed.

Some educators may feel that the T-SM-E Method would decide the learning for students before they do it. However, as the authors mentioned in this article it is not preferable to teach by using direct instruction. The authors prefer to use student-centered learning (Deboer, 2002) and active learning (Prince, 2004) in STEM lessons. However, in *How people learn* (NRC, 2000 p.11), it is pointed out that it does not mean that teachers do not need to teach anything to the students. In order for teachers to support their students in the engineering design process, they need to know about the learning objectives. These sequences support such teachers to anticipate and prepare for their students' learning. Thinking of it as professional development, teachers are the learners who should be the center. The authors prepared the T-SM-E method for teachers who want to study about STEM integration, but have difficulty understanding how the integrated four disciplines will appear in their lessons.

Basically, the Japanese Course of Study had been developed based upon the students' developmental levels and teachers and students had gotten used to the relationship between the contents and grade levels. If STEM is to be incorporated in the Japanese context, deeper understandings of developmental levels also would be required of classroom teachers. Furthermore, the skills to make the complicated contents more elementary are also needed for the same purpose. Further studies about how STEM will be integrated are needed during the next several years so teachers would know how they could integrate it in their lessons.

We cannot know the effects and the requirements for the integrated STEM Education without implementation. How can integration support students' learning? What kind of support is needed for lesson integration? What kind of curriculum is possible? What student outcomes can be identified in the integrated learning? To find answers to these questions, the authors plan to continue their project and expand the collaboration with teachers in schools. Thus, their STEM Education research in the upcoming years should be iterative design research on teachers' needs and for the integration needed in the classrooms of the future.



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